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HALF-PLANT LOW ALUM FEED WATER TREATMENT
AT F REACTOR

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INTERIM REPORT V, PRODUCTION TEST IP-549-A
HALF-PLANT LOW ALUM FEED WATER TREATMENT
AT F REACTOR

By

R. G. Geier
Process and Reactor Development Subsection
Research and Engineering Section

Classification Cancelled and Changed To

October 18, 1963

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By Authority of CG-PR-2,

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By Jerry Malin, 3-31-94

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INTRODUCTION

A half-plant low alum water treatment test⁽¹⁾ began at F Reactor on January 16, 1963. The test, which had been prompted by the analysis of ledge corrosion attack on fuel elements⁽²⁾, will demonstrate whether or not high alum feed is responsible for increasing the frequency of ledge and groove⁽³⁾ corrosion attack on fuel element surfaces. The effect will be evaluated by comparing visual examination results obtained from the normal production fuel irradiated in process water treated with two different alum feed rates. Four, 20 column fuel discharges, ten columns from each side of the reactor, have been taken during the test as follows:

1. One discharge prior to the start of the test⁽⁴⁾.
2. One discharge such that the test side was exposed to coolant treated with both high and low alum feed⁽⁵⁾.
3. Two discharges under test conditions⁽⁶⁾⁽⁷⁾.

This report discusses the results obtained from the third discharge under test conditions.

SUMMARY

The visual examination data from 620 F Reactor fuel elements, 310 from each side, which had been charged on June 19, 1963 and discharged September 9, 1963, gave the following results:

1. Primary ledge corrosion occurred on 23 per cent of the near side pieces and 21 per cent of the far side pieces.
2. None of the fuel elements exhibited primary groove corrosion.

It is evident that the combination of variables which produce ledge and groove corrosion has been changing gradually in a manner to produce a more severe environment. The point has now been reached where ledge corrosion is produced despite the benefits of low alum feed, but groove corrosion has not yet begun to appear.

DISCUSSION

A. Water Treatment

In order to determine whether high alum feed water treatment was responsible for an increased frequency of occurrence in the types of localized corrosion described as groove and ledge, the following half-plant test conditions were established at F Reactor on January 16, 1963.

	Control Side (Near)	Test Side (Far)
pH	7.0	7.0
Dichromate, ppm	1.0	1.0
Alum, ppm	18	6

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Test conditions were changed following startup from June 19, 1963 outage to:

	Control Side (Near)	Test Side (Far)
pH	6.6	6.6
Dichromate, ppm	1.8	1.8
Alum, ppm	18	6

The change was in conformance with the reduction in pH made at the smaller reactors to prolong process tube life. The actual alum feed rate used on the test side from the inception of the test through September is shown in Figure 1. On numerous occasions it was necessary to increase the feed rate above 6 ppm to produce coolant of acceptable quality. During the irradiation period of the fuel discussed in this report (June 19 - September 9), the alum feed rate to the test side averaged 8 ppm. Such a feed rate is considered satisfactorily below 18 ppm to demonstrate an alum effect if any.

B. Fuel Element Characteristics

Twenty columns of fuel elements, ten from each side of the reactor, which had been charged during the outage of June 19, 1963, were discharged during the outage of September 9, 1963. The average irradiation conditions are shown in the following table.

	Control Side (Near)	Test Side (Far)
Exposure, Mwd/t	683	672
Tube Power, kw	1065	1065
Tube Inlet Temperature, °C	17.5	17.5
Tube Outlet Temperature, °C	104	104
Tube Flow, gpm	46.7	46.7
Calendar Days in Reactor	82	82
Operating Days	75	75
Tube Age, Months	18	16
Fuel Charge	31 pc OIIIN + WM	31 pc OIIIN + WM

As has been the case with previous fuel discharges made during the production test, conditions on each side of the reactor were essentially identical.

For comparative purposes, the average irradiation conditions for all the fuel discharges made during the test are given in Table I. With very few exceptions, the irradiation variables have been held quite constant.

C. Visual Fuel Element Examination

1. Definitions

Visual fuel element examination identifies the serious type of corrosion attack as well as recognizing the presence of secondary effects. While

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a fuel element may exhibit several types of corrosion (pitting, uniform, ledge, or groove), only primary and secondary are reported, according to the following definitions:

Primary - Type of corrosion considered most detrimental to fuel survival.

Secondary - Type of corrosion, although less important than primary, which may be a potential cause of future corrosion problems.

The severity of corrosion is categorized as follows:

Code 2 - Corrosion judged to be 10 mils deep.

Code 3 - Penetration to the Al-Si.

2. Results

The analysis of the visual examination data from 620 fuel elements, 310 from the near side and 310 from the far side of F Reactor, produced the results shown below.

Localized Corrosion Frequency

	<u>Per Cent of Pieces</u>		
	<u>Near</u>	<u>Far</u>	<u>Over-all</u>
Primary Ledge	23.2	21.0	22.1
Secondary Ledge	0.3	0.0	0.2
Primary Groove	0.0	0.0	0.0
Secondary Groove	0.0	0.0	0.0
Severity - Code 2	0.0	0.0	0.0
Severity - Code 3	0.0	0.0	0.0

The results from previous fuel discharges made prior to and under the production test are shown in Table II.

There are several items of interest in connection with the results from the present fuel.

1. The frequency of ledge corrosion was high on both sides of the reactor. Thus, reducing the pH from 7.0 to 6.6 was not effective in preventing ledge corrosion. This confirms previous data from the half-plant low pH test at D Reactor⁽⁸⁾.
2. The fuel discharged May 6, June 19, and September 9, are quite indicative of a trend. No significant ledge corrosion was found on the May 6 fuel. Although the June 19 fuel exhibited 11.5 per cent ledge corrosion on an over-all basis, the

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ledging occurred on 21 per cent of the near side pieces and three per cent of the far side. In the present discharge, about 20 per cent ledging occurred on the pieces from both sides of the reactor. Therefore, we have a situation where the combination of variables responsible for ledge corrosion has been steadily increasing in severity. The combination during the irradiation of the May discharge fuel did not produce conditions severe enough for an alum effect to be recognized. During the irradiation of the June discharge fuel the combination of variables had reached a stage of severity such that when the difference in alum feed was superimposed upon it, an alum effect could be observed. The combination of variables shifted during the irradiation of the September discharge fuel to a severity which produced ledge corrosion despite low alum feed. Thus, it is clear that the use of high alum feed has only a secondary influence on the occurrence of ledge corrosion.

3. The continued absence of groove corrosion (no significant amounts have been seen since the beginning of 1963) is also of interest. It confirms the theory that as the combination of variables responsible for both ledge and groove corrosion shift to provide a more corrosive environment, ledging occurs first. If the present trend toward more severe conditions continues, it would be expected that groove corrosion would be found on the fuel scheduled for discharge during December.

In addition to identifying the most predominant types of corrosion, visual examinations also delineates the location of the primary corrosion as well as the location of hot spots and hot areas. There were 137 fuel elements exhibiting ledge corrosion and 115 fuel elements exhibiting hot spots or hot areas in the present fuel discharge. The location data for all occurrences of each are as follows:

	<u>Per Cent of Occurrences</u>	
	<u>Ledge Corrosion</u>	<u>Hot Spots and Hot Areas</u>
Bottom	76.8	4.4
Side	0.0	4.4
Top	2.9	91.2
Scattered	20.4	0.0

If only the 41 fuel elements which exhibit both hot spot - hot areas and ledge corrosion are considered, the location results are:

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	<u>Per Cent of Pieces</u>	
	<u>Ledge Corrosion</u>	<u>Hot Spots and Hot Areas</u>
Bottom	87.8	9.7
Side	0.0	7.3
Top	4.9	83.0
Scattered	7.3	0.0

The fact that the ledge corrosion occurs primarily at the bottom and hot spots and hot areas occur primarily at the top gives rise to some interesting speculation. It would tend to belie the importance of temperature as the single variable which is responsible for ledge corrosion. By the same token both the metallurgy of can components and fuel fabrication changes as single variables appear to be absolved since it would be inconceivable to charge in such a manner that nearly every surface area susceptible to ledging and grooving would be at the bottom. The data do suggest that flow perturbation occurring at the bottom may be of more importance than previously believed.

COUPON SAMPLES

During the pH 7.0 portion of the half-plant low alum test, coupon samples of aluminum alloys 1100, X-8001 and 6061, and carbon steel were exposed in the downstream spacer train of channels on both sides of the reactor. Equilibrium corrosion rates were calculated, and the ratio of corrosion rates in high alum feed coolant to the rates in low alum feed coolant are shown below(9).

<u>Alloy</u>	<u>Corrosion Rate High Alum Corrosion Rate Low Alum</u>
X-8001	0.82
1100	1.41
6061	1.94

The ratio of 0.82 for X-8001 does not indicate significant difference in corrosion. The 1.41 ratio for 1100 aluminum is marginal, and the 1.94 ratio for 6061 aluminum is significant in indicating higher equilibrium corrosion rates. Limited data from carbon steel samples indicate approximately the same corrosion rate in both types of water.

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FIGURE 1

ALUM FEED RATE - TEST HALF OF F REACTOR

TABLE I
AVERAGE IRRADIATION CONDITIONS
OF LOW ALUM HALF-PLANT TEST
FUEL DISCHARGES

	<u>Pre-Test</u>	<u>First Test</u>	<u>Second Test</u>	<u>Third Test</u>	<u>Fourth Test</u>
Discharge Date	1/3/63	3/29/63	5/6/63	6/19/63	9/9/63
Exposure, Mwd/t	565	940	645	650	685
Tube Power, kw	1125	1140	1160	1125	1065
Tube Inlet Temperature, °C	102.5	98	98.5	100	104
Tube Outlet Temperature, °C	14	7	7	10	17.5
Tube Flow, gpm	48.2	47.6	47.8	47.6	46.7
Tube Age, Months	9	11.5	12.5	14	17
Fuel Charge	32	31 + WM	31 + WM	31 + WM	31 + WM

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TABLE II

THE INCIDENCE OF LOCALIZED
CORROSION ON THE LOW ALUM
HALF-PLANT FUEL ELEMENTS

	<u>PT-216 Data</u>	<u>Pre-Test</u>	<u>First Test</u>	<u>Second Test</u>	<u>Third Test</u>	<u>Fourth Test</u>
Charge Date	----	10/1-11/3/62	11/22/62	2/19/63	3/29/63	6/19/63
Discharge Date	7/61-12/62	1/3/63	3/29/63	5/6/63	6/19/63	9/9/63
Primary Ledge	10.5	15.7	8.0	1.4	11.5	22.1
Secondary Ledge	4.5	4.3	1.2	0.0	0.6	0.2
Primary Groove	6.2	8.4	0.5	0.2	0.7	0.0
Secondary Groove	3.6	8.4	1.9	0.2	0.3	0.0

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